

Bibliography

- American National Standards Institute (1983). *Military Standard Ada Programming Language*. ANSI/MIL-STD-1815A-1983.
- Backus, J. (1978a). "The History of FORTRAN I, II, and III." *SIGPLAN Notices* 13, 8 (August 1978), pp. 165–180.
- Backus, J. (1978b). "Can Programming be Liberated from the von Neumann Style? A Functional Style and its Algebra of Programs." *Commun. ACM* 21, 8 (August 1978), pp. 613–641.
- Berry, D. M. (1971). "Introduction to Oregano." *SIGPLAN Notices* 6, 2 (February 1971), pp. 171–190.
- Clocksin, W.F., and Mellish, C.S. (1984). *Programming in Prolog*, second edition, Springer-Verlag, 1984.
- Cohen, J. (1981). "Garbage Collection of Linked Data Structures." *ACM Computing Surveys* 13, 3 (September 1981), pp. 341–367.
- DeRemer, F., and Kron, H. (1976). "Programming-in-the-Large Versus Programming-in-the-Small." *IEEE Transact. Software Eng. SE-2* (June 1975), pp. 80–86.
- Dijkstra, E.W. (1968). "Go To Statement Considered Harmful." *Commun. ACM* 11, 3 (March 1968), pp. 147–148.
- Goldberg, A. (1984). *Smalltalk-80: The Interactive Programming Environment*. Addison-Wesley, 1984.
- Goldberg, A., and Robson, D. (1983). *Smalltalk-80: The Language and its Implementation*. Addison-Wesley, 1983.
- Intermetrics, Inc. (1995). *Ada 95 Rationale: The Language, The Standard Libraries*. Intermetrics, 1995.
- International Standards Organization (1982). *Specification for Computer Programming Language Pascal*. ISO 7185-1982, 1982.
- International Standards Organization (1995). *Ada Reference Manual: Language and Standard Libraries*. ISO/IEC 8652:1995(E).
- Jensen, K., Wirth, N., Mickel, A.B., and Miner, J.F. (1985). *Pascal User Manual and Report*, third edition. Springer-Verlag, 1985.
- Johnston, J.B. (1971). "The Contour Model of Block Structured Processes." *SIGPLAN Notices* 6, 2 (June 1971), pp. 55–82.
- Kowalski, R. (1979). "Algorithm = Logic + Control." *Commun. ACM* 22, 7 (July 1979), pp. 424–436.
- MacLennan, B.J. (1990). *Functional Programming: Practice and Theory*. Addison-Wesley, 1990.
- MacLennan, B.J. (1983). "Values and Objects in Programming Languages." *SIGPLAN Notices* 17, 12 (December 1983), pp. 70–79; reprinted in Gerald E. Peterson (ed.), *Object-Oriented Computing, Volume 1: Concepts*, pp. 9–14. IEEE Computer Society Press, 1987.
- Manna, Z., and Waldinger, R. (1985). *The Logical Basis for Computer Programming*. Addison-Wesley, 1985.

- McCarthy, J. (1960). "Recursive Functions of Symbolic Expressions and Their Computation by Machine." *Commun. ACM* 3, 4 (April 1960), pp. 184–195.
- McCarthy, J. (1978). "History of LISP." *SIGPLAN Notices* 13, 8 (August 1978), pp. 217–223.
- Naur, P. (1978). "The European Side of the Last Phase of the Development of Algol 60." *SIGPLAN Notices* 13, 8 (August 1978), pp. 15–44.
- Perlis, A.J. (1978). "The American Side of the Development of Algol." *SIGPLAN Notices* 13, 8 (August 1978), pp. 3–14.
- Steele, G. L., Jr. (1984). *Common LISP: The Language*. Digital Press, 1984.
- United States Department of Defense (1980). *Reference Manual for the Ada Programming Language*, July 1980.
- Wirth, N. (1971). "The Programming Language Pascal." *Acta Inform.* 1 (1971), pp. 35–63.
- Wirth, N. (1975). "An Assessment of the Programming Language Pascal." *SIGPLAN Notices* 10, 6 (June 1975), pp. 23–30.
- Wulf, W., and Shaw, M. (1973). "Global Variable Considered Harmful." *SIGPLAN Notices* 8, 2 (February 1973), pp. 28–34.

Index

- . (period)
 - Pascal and Ada (selection), 184, 266, 269, 272, 274
 - Prolog (cons), 453–55
 - . (double period, “up to”), 175, 252
 - : (semicolon)
 - Prolog, 448, 468, 484
 - terminating vs. separating, 300–1
- : (colon)
 - functional programming (application), 360
 - Smalltalk, 425, 427
 - ‘ (LISP quote, “quote”), 315, 371. *See also* quote (LISP)
 - ` (single quotes), 21n
 - (. . .) (parentheses), 314–15, 319–20
 - { . . .} (braces in BNF, “either”), 153
 - [. . .] (square brackets),
 - Algol, 97, 118
 - BNF (“optional”), 154
 - functional programming (construction), 362
 - Pascal, 177, 180–81
 - Prolog (list), 453–55
 - Smalltalk, 408, 427
 - < . . .> (angle brackets), 150, 360
 - <> (less-greater)
 - set inequality, 177
 - unconstrained, 254–55
- <, > (less and greater relations), 174–75, 177
- = (equality or assignment), 99–100, 207, 471, 485–86
- == (equality), 100
- := (assignment, “gets” or “becomes”), 99–100
 - default parameter, 290
- ::= (“is defined as”), 150
- =.. (Prolog), 481
- :– (“if”), 447, 450, 450n
- ← (left-arrow, “gets” or “if”), 405, 450n
- ↑ (up-arrow), 99, 145, 189–91, 454–55
- ↑ (“return”), 411
- =>, 65, 289
- <=, >= (subset, superset), 177, 179
- \= (“not equal”), 447, 456, 482, 485–86, 488–89
- × (code duplication), 218
- / (reduction, “reduce by”), 360–61
- ! (“cut”), 476–80
- | (vertical line), 151, 454n
- [. . .] (local variables), 411
- (composition, “composed with”), 360–61
- @ (at-sign, display point), 406, 417
- + (plus, “union”), 177
- + (superscript plus, Kleene cross), 153
- (minus), 177
- (Ada comment), 265
- * (asterisk)
 - multiplication, 50
 - set intersection, 177
 - * (superscript star, Kleene star), 153, 156
 - ** (FORTRAN exponentiation), 50
 - (bar over constant, “constant”), 360
- ¹⁰ (subten, “times 10 to the”), 148
- α (alpha)
 - array addressing (“address of”), 71
 - functional programming (“apply to all”), 360
- 1, 2, . . . (boldface numbers, “first,” “second,” . . .), 360, 362
- abstract (Ada reserved word), 439
- Abstract vs. concrete operations, 244
- Abstract data type, 67–68, 174, 244, 253–54, 264–66, 319–20, 323, 327–28, 395, 412, 416–17, 443n, 452, 459
- Abstract declaration or subprogram (Ada), 439–41
- Abstraction, procedural or control. *See* Procedures
- Abstraction Principle, 17–18, 54–56, 105, 182, 194, 200, 271, 351, 356, 365, 400, 409, 412–13, 418–20, 423, 442, 496
- Abstract type language, 244, 305
- accept-statement, 294–99
- Access path, 185
- Access rights, 262–63
- Access types, 250, 269, 440. *See also* Pointer types
- Accuracy constraint, 254. *See also* Numeric data types
- Action and focus, 34, 77, 395
- Activation and deactivation, procedure, 62, 128, 220, 235, 238, 240, 294, 434–35
- Activation records, 61–66, 113–14, 127–28, 162, 211–40, 432–36
- block, 114, 235–38
- defined, 62
- nonrecursive procedure, 63
- recursive procedure, 212–14, 221, 232, 234
- Smalltalk, 432–36
- summarized, 239
- Active vs. passive, 421–22
- Actual parameter, 55, 162, 222, 227
- Ada, 117, 139, 169, 182–83, 188, 192, 194, 203, 205, 243–306, 366, 395, 399, 422–25, 427, 443
- Ada 95 language, 246, 286, 297, 303, 424, 436–41
- complexity criticized, 303–4
- history, 243–46, 303–4
- goals, 245
- name, 245
- Rationale, 306
- trademarked, 246
- addprop (LISP function), 330, 332
- Addresses. *See* Pointer types; References and referencing
- Addressing equation, 72
- Address modification, 9–10
- add1 (LISP function), 317–18
- add1-map (LISP function), 346
- adjoin (predicate), 486–87
- Aesthetics. *See* Elegance; Elegance Principle
- Agents, objects as, 426, 442
- AI, 309–12, 394–95, 446, 465
- Algebraic notation, 43, 88–89, 359, 362
- Algol-like language, 147, 162–63, 171
- Algol-W, 170, 183, 208, 446
- Algol-58, 95–96, 119, 162, 301
- Algol-60, 95–164, 179–81, 189, 194–97, 201–2, 205, 211, 228, 235–236, 249, 286, 299–301, 303–6, 344, 364, 366, 404, 436
- hardware for, 163
- history, 95–97, 99–100, 123–24, 144–45, 161–63, 167, 170, 173
- improvement on successors, 162–63
- racehorse rather than camel, 97
- Algol-68, 69, 117, 119, 162, 165, 170, 206–7, 251
- Aliasing, 82–85, 188, 202–3, 338–40
- a-list, 326–27, 378
- Allocation, static vs. dynamic, 76. *See also* Storage management
- all-pairs (LISP function), 347, 354–55, 357
- Alpha (Greek letter)
 - array addressing (“address of”), 71
 - functional programming (“apply to all”), 360
- Alphanumeric, 153
- Alphard, 244
- Alternates, 121, 379
 - in BNF, 151, 153–54
- Ampliative vs. reductive, 33–34, 162, 316, 396, 421, 480
- Analogies, 156–57, 493
- ancestor (predicate), 447
- and (LISP function), 344–45
- Angle brackets, 150, 360
- Annexes, special needs (Ada), 246, 303
- Anonymous
 - function, 353–55
 - procedure, block as anonymous, 238
 - type, 192, 252
- ANSI (American National Standards Institute). *See* Standards
- AP (activation record pointer), 218
- APL, 250, 359, 372
- append
 - LISP function, 328–30, 384, 454
 - Prolog predicate, 454–55, 484
- Apple computers, 405
- Application, function, 313, 339, 376–77
- Applicative language, 313, 339, 400. *See also* Functional programming; Function-oriented programming
- Applied value property, 332–33
- apply (LISP function), 380–85, 386–88
- apval (LISP property), 332–33, 343, 363
- AR (activation record), 64
- Arithmetic expression tree, 335, 455–58
- Arithmetic IF-statement, 46
- Arithmetic operations, 11–13, 68–69, 250, 253, 318, 417, 425–26, 471–74
- Arrays, 17–18, 70–75, 118–19, 179–83, 254–55. *See also* Indexing

- Ada, 254–55
 Algol, 112–14, 118–19
 base type, 180–81
 bounds checking, 29, 58, 180
 conformant array schema, 183
 declaration, 42, 98–99
 dimensions, 71, 74–75, 118, 146, 181–83
 dynamic, 99, 118–19, 162, 223n, 234
 flexible, 119
 FORTRAN, 70–75
 implementation, 71–75
 index constraint, 254–55
 index type, 180–81
 initialization, 42
 lower bounds, 98, 118
 parameters, 57–58, 128–29, 182–83, 254–55
 Pascal, 179–83
 passed by reference, 57–58
 passed by value, 128–29
 pseudo-code, 17–18
 row- vs. column-major order, 72
 Arrow symbols. *See Symbols at beginning of index*
 Artificial intelligence, 309–12, 394–95, 446, 465
 Assembler, 9
 structured, 206
asserta (predicate), 475, 477–79
Assertions (Prolog), 447
assertz (predicate), 475
 Assigned GOTO-statement (FORTRAN), 49–51
 Assignment statement, 16, 43, 400, 405
 record assignment, 184–85, 191–92
 symbol, 99–100, 207, 290
ASSIGN-statement (FORTRAN), 49–50
 Assistant, Programmer's, 397–99
assoc (LISP function), 327, 378, 384
 Association lists, 326–27, 378
 Asterisk
 vs. double asterisk, 50
 on exercises, 16n
 Kleene star, 153, 156
 set intersection, 177
 atom (LISP function), 319–20
atomic (Prolog predicate), 456–57
 Atoms, 314–15, 317–19, 331–34, 343, 486
 etymology, 317
 nonnumeric, 318–19, 378–79
 numeric, 317–18, 377–78
 properties, 331–34, 340–41, 363–64, 442
 representation, 340–41
 simulate objects, 331–34, 411–12
 At-sign, 406, 417
 Automatic coding, 37, 39
 Automatic deduction or theorem proving, 446, 459–60, 466, 469, 475–76
 Automation Principle, 10, 17, 456, 496
- B (programming language), 206–7
 Babbage, Charles, 245
 Backtracking, 466–69, 475–80, 484–85
 Backus, John, 39–40, 96, 148–50, 359–63
 Backus-Naur (or Normal) Form. *See BNF*
 Backus's FP language, 359–63
 Backwards execution, 452, 466–69, 472–74
 Baroque language or feature, 138, 140, 164, 206
 Bar symbols. *See Symbols at beginning of index*
 Base language, 168
 Base type, 176, 180–81, 191
 BASIC, 118, 250
 BCPL, 206–7
- begin-end.** *See Block; Compound statement*
 Bell Labs, 11, 206–7
 Billington, David P., 157–60
 Binary
 operator, 356
 representation of numbers, 67
 reversing arguments, 357
 to unary, 355–56, 360
BINARY FIXED (31), 249
 Binding. *See also Declarations*
 argument, 355–57
 class. *See Class*
 formal parameter, 55
 object, 405
 Prolog instantiation, 454, 472
 temporary, 364–67
 Binding constructs (bindings). *See Declarations*
 Binding time, 29, 42–44, 100–101, 138, 197, 441
 parameter inspection time, 134
 Blanks, ignoring, 86–87
 Blocks and block structure
 Ada, 300
 Algol, 101–7, 112–14, 162
 vs. compound statement, 101–2, 124
 implementation, 235–39
 limitations, 258–63
 LISP, 364–67
 Pascal, no blocks in, 196
 Smalltalk, 427
 stack storage management, 112–14
 two-coordinate addressing, 215–17, 240, 433
 BNF, 96–97, 124, 148–56, 163
 Chomsky type 2 grammar, 155
 context-free grammar, 154–56
 etymology, 150
 extended, 153–54
 grammar size, 303–5
 Body, 248, 265
 of Prolog clause, 450, 465
 Boldface, 97, 145, 171, 362
 Boole, George, 66n
 Boolean type and values, 66, 98, 115, 319
 Bottom-up control, 463–65
 Bounds checking, 29, 58, 180
 Box (class or package), 409–11, 416–17, 423–24, 431, 437–40
 Braces, curly, 153
 Bracketing, statement, 123–24, 301–2, 408
 Brackets. *See also Symbols at beginning of index*
 angle (()), 150, 360
 curly ({}), 153
 round, 314–15, 319–20, 370–72
 square ([]), 97, 118, 154, 176, 180–81, 362, 408, 427, 453–55
 Breadth-first search, 474–75
 Breakpoints, 26
 Bridge, Tacoma Narrows, 158–59
 Bruner, Jerome, 404
 bu (functional), 355–58, 360, 370
 Buffer, 267–68, 296–97
 Burroughs B5500, 163
 bu2, bu3, etc. (LISP functionals), 357
 By-copy and by-reference parameters, 286n.
 See also Parameter passing modes
 Byron, Lord George Gordon (poet), 245
- C (programming language), 100, 117, 206–8, 251, 304, 389–90, 399, 436, 441
 By-copy and by-reference parameters, 286n.
 See also Parameter passing modes
 Calculus (Prolog example), 451, 455–58
- Call, implementation. *See Procedures, implementation*
 call (Prolog)
 predicate, 481
 trace, 470
 Callee vs. caller, 55
 Call in environment of caller or of definition.
 See Scoping, static vs. dynamic
 Cambridge Polish notation, 313, 318
 Capitals, 31n, 450
 car (LISP function), 320–23, 360
 etymology, 337
 Prolog definition, 452–55
 Card columns, 30–31, 86–87, 143–44
 Cartesian product, 347–48
 Case selection, 47, 139–40, 199–201
 default, 210
 fall-through, 140
 implementations, 201
 switch-declaration, 98–99, 139–40, 199
 Casting. *See Type conversions*
 Catchers (LISP), 388n
 Categories, syntactic, 150. *See also Nonterminal symbols*
 cdir (LISP function), 321–23, 360
 etymology, 337
 Prolog definition, 452–55
 Cdr-encoding, 342
char, Pascal data type, 173
 Character data type, 70, 173, 255–56. *See also Atoms; Strings*
 Characteristic (floating-point numbers), 67
 Character set, 144–45, 255. *See also Lexics*
 Character strings, 69–70
 Chomsky, Noam, 154–55
 Chomsky hierarchy, 154–55
 Circle (small), composition, 360–61
 Circular structures, 340, 391–92, 429
 Class, 163, 244, 277, 404, 408–21, 431–32, 441, 444. *See also Packages; Subclass*
 class (Ada type), 440
 class (Smalltalk class), 431
 Smalltalk built-in, 415
 Class method, 410–11
 Class protocol, 412, 416–17
 Class variable, 431
 Clauses (Prolog), 447, 449–50, 469–71
 Horn, 450, 482–83, 489
 order of, 450, 461
 CLOS (Common LISP Object System), 421, 441–42
 Closed-world assumption, 458–59, 482
 Closures, 225–28, 240, 385–88
 CLU, 244
 COBOL, 66, 86, 91, 117, 161, 167, 183, 250
 Code vs. data, 9–10, 315–16, 421–22
 Code generation or synthesis (compilation), 44, 248
 Coding conventions, 16, 125
 Coercions, 68–69, 116, 120, 417–18, 441
 Cognitive models, 14, 134–35, 321
 Cognitive science, 134–35, 404
 Colmerauer, Alain, 446, 460
 Colon symbols. *See Symbols at beginning of index*
 Column-major order, 72
 Columns, card, 30–31, 86–87, 143–44
 Combinator, 357–58. *See also Functional*
 Combinatorial power, 357–58
 Combining form, 357–58. *See also Functional*
 COMMON block, 81–84, 268
 Common LISP, 312, 313n, 315, 318, 399–400, 421, 440. *See also LISP*
 comp (LISP functional), 358, 360
 Comparisons, 15

- Compatibility, upward, 305
 Compatible types, 253
 Compilation, 56, 195, 248, 265–66, 274–76,
 279, 291
 Compilers, 11, 30–33, 36–37, 43–44, 86, 248
 compatible, 395, 398
 implemented in own language, 206
 validation, 246
 Compile-time vs. run-time, 11, 36–37, 41–44,
 100, 215–18
 Compiling routines. *See* Compilers
 Complex data type, 66, 115–16, 264–65, 416
 Complexity, 183, 204, 250, 256, 440–41. *See also* Simplicity Principle
 and elegance, 158
 featuritis, 304–5, 441
 metric, 303–5
 of programming, 7–8
 Components, record, 183–84
 Composite types, 286
 Composition, function, 358, 360–61
 Compound statement, 101–2, 124–25, 301
 Compound term. *See* Term (Prolog)
 Computed GOTO, 47, 199, 201
 Computer language, vs. programming
 language, 1
 Conceptual models, 14, 134–35, 321
 Concrete vs. abstract operations, 244
 Concurrency, 240, 245, 291–99, 305–6,
 427–28, 435–36, 442, 465–66
 Concurrent Pascal, 205, 306
 cond (LISP conditional), 314, 344
 Condition, 198, 379
 Prolog clause, 450
 Conditional logical connectives, 344–45,
 349–50, 379
 Conditional selection, 15, 46–48, 127, 310,
 343–45
 Algol vs. FORTRAN, 121–23
 conditional expression, 127, 140, 310, 343–44
 consequent and alternate, 121, 379
 dangling **else** problem, 147
 LISP. *See* cond (LISP function); if
 (LISP function)
 multiway, 302
 Conformant array schema, 183
 cons (LISP function), 320, 327–29, 337,
 388–89
 Prolog definition, 452–55
 Consequent, 121, 379
 Consistency, automatically maintained, 398
 const
 LISP functional, 358–60
 Pascal constant declaration, 193
 constant (Ada), 256
 Constant, changed via reference parameter,
 59–60
 Constant declarations, 172, 193–94, 256–57
 Constant function, 358–60
 Constraint
 accuracy, 254
 discriminant, 254
 fixed-point, 250
 index, 254–55
 range. *See* Range constraint
 Construct (declarative vs. imperative), 41–42,
 98–99
 Constructor (functional), 362
 Constructor, inverse, for selection, 454–55
 Constructors vs. primitives, 70, 75, 101, 320,
 327–28
 consval (LISP function), 353, 355–56, 383
 Context, 78, 103–4, 111–12, 212, 222,
 237–38, 240, 375, 378, 382–88. *See also*
 Environment; Name structure; Scoping
 Contextual error correction, 396
 Context clause, 266
 Context-free grammar and language, 154–56
 Context-sensitive grammar and language, 154
 Contextual error correction, 396
 CONTINUE statement, 51–52, 123
 Continuous data types. *See* Floating-point
 numbers.
 Contour diagram, 79–80, 99, 102–103, 214.
 See also Name structure; Scoping;
 Visibility
 dynamic vs. static scoping, 107–9, 368–69
 Control abstractions. *See* Procedures
 Controlled variable, 51
 Control vs. logic, 461, 469, 473–74, 480,
 489–91. *See also* Bottom-up control;
 Top-down control
 Control structure, 44–65, 92, 121–40, 164,
 196–204, 281–85, 408, 461, 489. *See also*
 specific control structures
 Conventions, 31n. *See also* Coding
 conventions
 Conversions, type, 68–69, 120, 250, 255. *See also* Coercions
 Copy-restore, 60–61, 286–88
 Copy rule, 56–57, 129–35, 140
 Core language (Ada), 246, 303
 Coroutines, 240
 Coupling, loose vs. tight, 296
 cousin (predicate), 447
 CPL, 206–7, 210
 Creeping Feature Syndrome, 304–5, 441
 Cross, Kleene, 153
 Culture, 36. *See also* Conventions; Style
 Cut (Prolog), 476–80, 483
 Cyclic structures, 340, 391–92, 429
 C++ (programming language), 207, 304,
 421, 441
- D (display element), 231
 d (predicate), 451
 Dangling **else** problem, 147
 Dangling pointer or reference, 292–93, 389
 Dash, double (Ada comment), 265. *See also*
 Minus sign
 Data abstraction language, 244, 305
 Data vs. program, 9–10, 315–16, 421–22
 DATA statement, 42
 Data structure, 66–75, 92, 115–21, 163,
 172–93, 248–56, 317–41, 450–61. *See also*
 specific data structures
 manager, 268–69
 Data traps, 26
 Data type, abstract. *See* Abstract data type
 date (record type), 184
 DayOfMonth (data type), 175–76
 DayOfWeek (data type), 174
 Deactivation. *See* Activation and deactivation,
 procedure
 Dead-lock, 295
 Debugging, 24–26
 Decimal numbers, 33, 39
 Decimal point, 145
 declare (Ada), 266, 269, 274, 277–78,
 283, 300, 366
 Declarations, 76–77, 193, 257. *See also*
 Executable statements vs. declarations
 Ada, 247, 302
 binding constructs (bindings), 75–76, 193
 class, 409–421, 440
 constant, 172, 193–94, 256–57
 deferred, 257, 265
 definition vs. specification, 248
 dynamic in LISP, 317
- FORTRAN, 42
 implicit bindings (enumeration types),
 173–75, 255–56
 implicit bindings (for-loop), 283
 LISP, 316–17, 363–67
 module, 264–78, 409–415, 436–440
 object (Ada), 248
 optional, 77, 87
 order, Pascal, 195–96
 overloading. *See* Overloading
 package, 264–78, 436–440
 Pascal, 193–96
 procedure, 54–56, 78–80, 99, 127, 172,
 194–96, 257, 340, 409–11
 switch, 98–99, 139–40
 task, 248
 type, 172, 191–3, 196, 248–54
 variable, 28–32, 75–78, 127–28, 172, 256,
 363–64, 405, 412
- Declarative vs. imperative. *See also*
 Executable statements vs. declarations;
 Imperative
 languages, 313
 statement, 98–99
 Decoding, instruction, 23–24
 Deduction, automatic, 446, 459–60, 466, 469,
 475–76
 Defense in Depth Principle, 50–51, 87, 496
 Deferred constant, 257, 265
 define (LISP function), 370–71
 Definitions. *See* Declarations
 defun (LISP pseudo-function), 314, 317,
 363–64, 370–71, 391n
 delprop (LISP function), 330
 delta, 250
 Denotations
 integer, 71
 numeric, 148–54
 Department of Defense, U.S., 244–46, 303–4
 Dependencies, implicit, 193–94
 Depth-first search, 469–71, 474–75, 487
 DeRemer, F., 56n
 Derived type, 251–54, 438
 Descriptive tools, 148–50
 Design, feature vs. language, 305
 Design, responsible, 114–15, 188–89, 389,
 496
 Designer's model, 135
 Dewey, John, 404
 Diagnostics in extensible languages, 169
 Diagrams, 148
 contour. *See* Contour diagram
 Dialects. *See* Subset, language; Superset,
 language
 diff (predicate), 451–52, 455
 difference (LISP function), 317
 Difference, set, 177
 Differentiation, symbolic, 451, 455–58
 digits, 249
 Dijkstra, E. W., 48–49, 90, 126, 167–68, 243
 DIMENSION statement, 42
 Discrete type, 176, 180. *See also* char;
 Character data type; Integers
 Discriminant
 of quadratic equation, 110
 of tagged type, 437
 variant record, 187, 251
 Discriminant constraint, 254
 Discriminated union, 251. *See also* Variant
 record
 Display method, 162, 231–34, 238–39
 Display object (class), 413–15, 418–20,
 436–40
 dispose, 263, 389
 distl (function), 347, 354–56, 361

- distr** (function), 362
Distribute left, 347, 354–56, 361
Distribute right, 362
DL (part of activation record). *See* Dynamic link
DoD, 244–46, 303–4
DO-loop, 51–53, 73–75, 85. *See also Iteration*, definite
 vs. Algol **for-loop**, 122
 nesting, 123
 syntactic problems, 86–87
Domination (numeric types), 69
Dot notation. *See* Period, single
Dotted pair, 326n, 453–55
Double precision numbers, 66, 115. *See also Numeric data type*
Do What I Mean, 396–99
Drum computers, 8
Dummy variable. *See* Formal parameter
DWIM, 396–99
Dynabook, 404–5
Dynamic chain, 62, 162. *See also* Dynamic link
Dynamic link, 62, 219–221, 223–25, 236–38, 433, 435. *See also* Dynamic chain
Dynamic vs. static, 100, 118–19. *See also Storage management; Typing scoping; Scoping, static vs. dynamic*
Dynamic vs. static structure. *See* Structure Principle
Dystopians vs. utopians, 33–34, 40, 389
Economy, 157–58, 244, 303
Editor
 structure, 397–98, 401–2
 syntax-directed, 248
Efficiency
 of Ada parameters, 286–88
 and C, 207–8
 of case statement, 201
 and C++, 441
 display procedure call, 233
 display vs. static chain, 234
 display summarized, 234
 display variable access, 231–32
 of enumeration types, 175
 of extensible languages, 169
 fixed-point, 250
 and FORTRAN, 39–40, 57–58
LISP, 399
 of Pascal parameters, 202
Prolog, 461, 463–66, 474–75, 480, 490
 of set types, 178–79
 static chain procedure call, 224
 static chain summarized, 230
 static chain variable access, 218
 of subrange types, 176
 Three E's, 157, 303
Elegance, 156–61
Elegance Principle, 158–59, 179, 205, 372, 442, 496
Elementary types, 286
Elements of Style by Strunk and White, 14
elsif, 302
Embedded software, 244, 250
Embodiment, 34
empty (Prolog), 486–87
Empty statement, 300–1
Enabling capabilities, 399
Encapsulation mechanisms, 163
end, overused in Algol and Pascal, 301
Englebart, Douglas, 404
entry
 Ada concurrency, 293–99
 procedure implementation notation, 64
Enumeration types, 173–75, 209, 255–56
Environment (name structure), 41, 78–82, 107–14, 194–96, 258–263, 372, 412–15.
See also Context; Name structure; Scoping
 of caller vs. of definition. *See* Scoping, static vs. dynamic
 defined, 78
 disjoint, 78
 implementation, 211–218, 231–239, 378, 431–434
 opening, 185
Environment, program development, 395–99, 443
Interlisp, 396–99, 443
 programming language as work environment, 160
Smalltalk, 443
Environment part or pointer, 212, 214, 221n, 226, 232, 240, 385–86, 433–34
EP. *See* Environment part or pointer
EP-IP pair. *See* Closures; Locus of control
eq (LISP function), 319, 332
 vs. **equal**, 348
.EQ. (FORTRAN equality), 46
equal
 vs. **eq**, 348
 LISP function, 348–50, 486
 Prolog predicate, 459
Equality relation, 46, 319, 348–50. *See also Inequality*
 Prolog, 471, 485–87
Equal symbols. *See also* Symbols at beginning of index
 assignment vs. equality, 99–100, 207
 unification, 471
Equivalence type, 191–93, 251–54
EQUivalence declaration, 84–85, 113
Equivalence relation, 486–87
Erasure, automatic vs. explicit. *See* Storage reclamation
Error correction, automatic 396–99
Error handlers, 268–69, 284–85, 306–7, 388n
Euclid (language), 205, 244–45
Euler (language), 170, 208, 245
eval (LISP function), 375–88, 395
evargs (LISP function), 380–81
Exceptions, 268–69, 284–85, 306–7, 388n
Exclamation point, 476–80
Executable statements vs. declarations, 20, 26–27, 41–42, 76. *See also* Declarative vs. imperative; Imperative
Executable unit, 239–40
Exit (Prolog trace), 470
exit-statement, 281–83
Experience, in design, 14, 136, 160
Experimental software development, 394–95, 398
Explicit erasure. *See* Storage reclamation
expr (LISP property), 333–34, 343, 363–64
Expression tree, 335, 455–58
Extended BNF, 153–54
Extensibility, 163, 168–69, 208, 367, 398–99, 414–15, 417, 423
Extension, programming by, 436
Extension of behavior, 414
Extent of loop, 51
External references, 44
External representation, 276–78, 412, 418, 423–24, 436, 441–42
Extrapolation, amplificatory, 34, 138, 140, 162, 421, 445
fac (predicate), 476–77
Facts (Prolog), 447, 449–50
fail (Prolog)
 predicate, 483
 trace, 470
Fascination vs. fear, 34–35, 138, 140
father (predicate), 447
Fear vs. fascination, 34–35, 138, 140
Feature interaction, 51, 77, 86–87, 136–37, 158–59, 181–83, 290–91, 302, 304–5
Featutris, 304–5, 441
fib (predicate), 462–69, 471–74
Fibonacci numbers, 462–69, 471–74
Fifth-generation, 306, 309, 400–1, 421, 443–44, 497. *See also* Generations
File system, Interlisp, 398
filter (LISP function), 352
Filtering of list, 346–47, 352
Finite discrete type, 180. *See also* Discrete type
Finite mapping, 181
Finite sets. *See* Sets
First
 array attribute, 255, 282n
 LISP function, 337
First-class citizen, 70, 116–17, 204, 228, 277, 442
First-generation language. *See* Generations
first-order logic, 481
Fixed vs. free format, 30–31, 86–87, 143–44
Fixed point of function, 460
Fixed-point types, 249–50. *See also* Numeric data types
Flag value, 20
FLEX, 404
Flexible arrays, 119
Float, 249
Floating-point numbers, 9–10, 36, 39, 66–69, 249
FLOW-MATIC, 66
FLPL, 310
Focus and action, 34, 77, 395
for-loop, 137–38. *See also* Iteration, definite
 Algol vs. DO-loop, 122
 Algol vs. Pascal while-loop, 122
 baroque, 137–38
 for-list-element, 137
 often unnecessary in LISP, 345–46
 Pascal, 197
Formal parameter, 54–55, 162, 353–54, 363–64, 382–84. *See also* Parameter passing modes
Form and function, 13, 159
Format, fixed vs. free, 30–31, 86–87, 143–44
FORTRAN, 39–92, 117–23, 146, 161–62, 167, 170, 172–73, 179–81, 189, 197, 202, 211, 220, 249, 268, 286, 305–6, 309–11, 343, 364, 446
 as cockroach, 93
 history, 39–40, 90–91
 lost space probe, 87
 name, 40
 predicted use in year 2000, 93
 Zero-One-Infinity violated, 117–18
forward declaration, 195–96
Fourth-generation language, 5n, 305–6. *See also* Generations
FP. *See* Backus's FP language; Functional programming
Framework, language, 494–95
Free-list, 389, 393. *See also* Storage reclamation
Free vs. fixed format, 30–31, 86–87, 143–44
Free storage area, 337, 388–394, 428–30, 432–36
Free union, 251
Freq (LISP list), 312, 320

- Fully bracketed syntax, 301–2
funarg, 386n. *See also* Closure; Upward funarg problem
funcall (LISP function), 356n
Function. *See also* Procedures
 anonymous, 353–54
 and form, 13, 159
 FORTRAN FUNCTION, 57, 123
 level vs. object level, 359
 LISP function, 356, 370, 385–88
 Pascal, 203
 pseudo-, 316, 339
 pure, 316, 321, 328, 338–39
 as typed procedure, 99
 Functional, 352–57, 359–63. *See also*
particular functionals
 defined, 355
Functional arguments. *See* Functional;
 Functional Programming; Parameter
 passing modes, functional
Functional programming, 309, 355–63,
 400–401. *See also* Functional; Function-
 oriented programming
 Backus’s language, 359–63
 defined, 355
 dynamic scoping, 367–70
 implementation, 228
 filtering, 346–47, 352
 mapping, 346, 351–52, 357–58, 360, 427
 in Prolog, 480–81
 reduction, 346, 352, 357–58, 360–61, 480–81
Function cells (Common LISP), 334n
Function-oriented programming, 306, 309,
 312–17, 400–401, 421–22, 443–44
Functor, 451
 • Garbage collection, 392–94, 441. *See also*
Storage reclamation
Generality. *See* Regularity Principle;
 Simplicity Principle; Zero-One-Infinity
 Principle
Generations, 5, 92, 138, 163–64, 207–8,
 305–6, 400–401, 443–44, 489. *See also*
Fifth-generation; *Fourth-generation*
 language
 reasons for shift, 158
Generic operators, 68. *See also* Overloading
Generic packages, 270–76, 423–24, 441
get (LISP function), 332
getprop (LISP function), 324–25, 332
getproplist (LISP function), 334n
Global, 78–79, 104, 162, 364. *See also* Name
 structure; Scoping; Visibility
 considered harmful, 258–63
Goals (Prolog), 447–48, 450, 465
 Gödel’s incompleteness theorem, 481
go: message, 407–8
 Go to controversy, 126. *See also* Structured
 programming
goto statement, 15–16, 45–51, 91, 125–26,
 135–36, 164, 172, 198, 228–30, 281
 nonlocal, 135–36, 228–30
switch-declaration, 98–99, 139–40
goto: message, 406–7, 413–15
GRAIL, 404
Grammar. *See* BNF
 Grammar size, 303–5
grandparent (predicate), 447
Graphics, turtle, 406–10
Greater-or-equal relation, 177
Greater-than relation, 48, 174–75, 177
Green, Cordell, 446
grow: (message), 410
.GT. (FORTRAN greater-than), 48
Guards (guarded entries), 297–98
- Hamming**, R. W., xv–xvi, 3
Handler, exception, 268–69, 284–85, 306–7,
 388n
Hardware representation, 145
Hayes, Pay, 446
Head of Prolog clause, 450, 465
Heap storage management, 337, 388–394,
 428–30, 432–36
Heterogeneous data structure, 185–86
Hidden parameter, 255
Hierarchical structure, 46–48, 52–53, 89–90,
 97–98, 144, 301–2
 and BNF (context-free) grammar, 155–56
 classification (Smalltalk), 412–15, 418–21,
 443
LISP equality, 348–50
 nested statements, 122–26
Higher-Order Language Working Group,
 244–45, 249
High level. *See* Level, higher vs. lower
Hilfinger, Paul, 307
History, 7–11, 36–37, 39–41. *See also*
individual programming languages
 Santayana on, 3
History list, 397
Hoare, C. A. R., 29, 167, 170, 183, 188, 200,
 304–5, 307
Hollerith, Herman, 69n
Hollerith constant, 69–70
HOLWG, 244–45, 249
Homogeneous data structure, 185–86
Hopper, Grace Murray, 11, 39
Horn clause form, 450, 482–83, 489
Hypotheses (Prolog facts), 447, 449–50, 465
- IAL** (International Algorithmic Language),
 95–96, 119, 162, 301
IBM
 and Algol, 96, 162
 and FORTRAN, 39–40
 360 computer, 249
 650 computer, 8, 11
 701 computer, 39
 704 computer, 9, 36, 39–40, 45–46, 66,
 161, 206, 311, 337
Ichbiah, Jean, 245
Identifiers (names), 76, 117–18, 146. *See also*
Name structures
Identity of Indiscernibles, 485
if (LISP function), 324–25, 344, 377, 379
if (Prolog), 450n
IF-statements, FORTRAN, 45–49, 122–23
if-then-else. *See* Conditional selection
Ihde, Don, 33–35, 404
Image, system, 135
Imperative, 31n, 43, 45, 98–100, 345n. *See*
also Executable statements vs.
 declarations
 language, 313, 339
 programming in Prolog, 471–74, 477–80
Implementation dependence and
independence. *See* Machine dependence
 and independence; Portability;
 Portability Principle
Implementation vs. specification, 257
Implicit bindings (enumeration types),
 173–75, 193, 255–56
Implicit inheritance, 104–5, 262
Importation, 262, 264, 266
Impossible Error Principle, 12, 52, 58, 106,
 180, 191, 496
in
 Ada passing mode, 286–88
 Pascal set membership, 177, 179
- Indenting**, 124–5, 143–44. *See also*
Structured programming
Index constraint, 254–55
Indexing, 9, 17–18, 36, 39, 53, 73–75,
 180–81. *See also* Arrays
Index registers, 73–75
Index type, 180–81
Indicator, 324
Indiscriminate access, 107 258–60, 262–63
Inequality, 482, 485–86, 488–89
Infinite terms, 459–60. *See also* Lists, circular
 or cyclic
Infix format, 31, 451, 453, 455–56
Information hiding, 78, 245, 257, 263–65,
 280, 305, 496. *See also* Information
Hiding Principle
Information Hiding Principle, 81, 107, 263,
 408–9, 416, 426, 429, 433, 435, 442. *See*
also Information hiding
Ingerman, P. Z., 132
Inheritance
 class, 413–15, 418–21
 implicit vs. explicit, 104–5, 262
 multiple, 421, 441–42
Initialization, 28–29, 42, 256
Inner product, 352, 360–63
in out (Ada passing mode), 286–88
Input-output, 18–19, 43, 161, 197, 474
I-N Rule, 77
Inspection time, 134. *See also* Binding time
Instance method, 410
Instance variable, 409–11, 429–31, 433–34
Instantiation, 127–28, 240, 271
 object, 408–9, 431
 Prolog, 454, 472
 static vs. dynamic, 272, 277, 423–24
Instruction decoding, 23–24
Instruction part or pointer, 21–22, 212, 221n,
 226, 240, 385–86, 388, 433
Integers, 67, 115. *See also* Numbers; Numeric
 data types
 vs. enumeration types, 173–74
 Prolog definition, 451–52
 Smalltalk, 408
Integrated programming environment. *See*
Environment, program development
Interface, manifest, 316–7, 416, 496
Interface overhead, 37, 169
Interface specification, 248, 257, 305, 395,
 398
Interim Dynabook, 404
Interlisp, 312, 396–99, 402
Intermediate form, 32
Internal representation. *See* Representation,
 internal vs. external
International Algorithmic Language (IAL),
 95–96, 119, 162, 301
Interpreter
 efficiency, 11, 23–24, 36–37, 39, 399
 iterative (pseudo-code), 21–33, 375
 origin, 10
 recursive (LISP), 310–11, 375–388
 universal function, 310–11, 375
Intersection, 177, 179
Intuition pump, 157
Invariant code, removing from loop, 74
Inverse functions, 452, 466–69, 472–74
Invocation (procedure call), 55. *See also*
Procedures
IP. *See* Instruction part or pointer
ip (function), 352, 360–63
IP-EP pair, 214, 240
IPL, 309
Ironman, 245
is (Prolog), 471

- ISO (International Standards Organization). *See* Standards
 Iteration, 281–84, 376–82
 Ada loop, 281–283
 Algol **for**-loop, 122
 and bottom-up control, 463–65
 definite, 17–18, 51–53, 122, 137–38, 197, 282–83, 408
 indefinite, 47–49, 198, 426
 infinite, 281, 426
 leading-decision, 47, 198, 282
 mid-decision, 48, 198, 282
 optimization, 73–75
 Pascal **for**-loop, 197
 vs. recursion, 345–47, 350
 Smalltalk, 408, 426
 trailing-decision, 47, 198
 I Through N Rule, 77
 Iverson, Ken, 372
- Java (programming language), 390, 441
 Jensen's device, 110, 131–32, 313
 Johnston, John B., 79
 JOVIAL, 96
- Kay, Alan, 403–4, 421, 442–44
 Kernel language, 168
 Kernighan, B., 207, 210
 Keywords, 145–46. *See also* Reserved words
 Kleene, S. C., 153n
 Kleene star and cross, 153, 156
 Knuth, Donald, 141, 165
 Kowalski, Robert, 446, 461n, 491
 Kron, H., 56n
- Label, statement, 26–28, 49–51, 193, 196, 198, 228–30, 240
 Labeling Principle, 26, 200–1, 289, 425, 496
 Label table, 27–28
 LABEL type, 51
 lambda (LISP form), 334, 353–55, 385–88
 Lambda calculus, 353
 Lambda expressions, 354–55, 385–88, 427
 Landin, Peter, 126
 Languages, 1–2. *See also* Programming language
 formal, classes, 154–56
 object vs. metalinguage 150–51
 reference vs. publication, 145
 Laning and Zierler system, 39–40, 89
 Large, programming in the, 56, 357–58
 Last, array attribute, 255, 282n
 Leading-decision loop, 47, 198, 282
 left (field), 335, 36, 300, 307
 length (LISP function), 327, 359
 Lenient interpretation of logical connectives, 344–45, 349–50, 379
 Less-greater symbol (<>, 177. *See also* Angle brackets
 Less-or-equal relation, 177, 179
 Less-than relation, 48, 174–75, 177
 let (LISP function), 366–67
 Level, higher vs. lower, 10, 36, 51–52, 175, 177, 188–89, 351, 359, 441, 445–46, 490
 Lexics and lexical analysis, 30–33, 85–88, 143–46
 Libraries, 11, 36–37, 44, 56, 267
 Library items, 266
 LIFO (last-in, first-out), 113–14, 436
 Linear structure, 89–90, 92. *See also* Hierarchical structure
 Linking, 43–44
 lint, 207
 Lisa computer, 405
- LISP, 250, 302, 309–401, 405, 411–2, 422, 436, 441–43, 446, 452–55, 480–81, 490. *See also* Common LISP
 dynamic scoping, 107, 112, 365–70, 385–88
 history, 309–12, 396, 399–400, 441–42
 LISP 2 language, 311, 370, 400
 longest still in use except FORTRAN, 311
 “Lots of Idiotic Single Parentheses,” 371
 machines, 399, 402
 programs represented by lists, 315, 371–2, 395
 list
 LISP function, 347, 354
 Prolog predicate, 453
 Lists, 309–11, 314–16, 319–40, 452–56
 association, 326–27, 378
 cdr-encoding, 342
 cell, 335
 circular or cyclic, 340, 391–92, 429
 editor, 397–98, 401–2
 implementation, 334–36
 left and right parts, 335
 null (empty), 319
 Prolog implementation, 452–55
 property, 324–26
 recursive construction, 328–30
 represent programs, 315, 371–2
 shared sublists, 338–40
 Literals
 numeric, 71, 148–54
 Prolog, 450
 Literal table, 59, 128
 Loaders and loading, 19–20, 24, 27–28, 30, 32, 43–44
 Local, 78, 104, 162, 198, 382–84, 411. *See also* Name structure; Scoping; Visibility
 in activation record, 213
 multiple instantiation of local variables, 127–28, 213
 Localized Cost Principle, 138, 206, 290, 495–96
 Locus of control, 214, 240
 Logic, first-order vs. higher-order, 481
 LOGICAL (FORTRAN data type), 66
 Logical IF-statement
 Logic vs. control, 461, 469, 473–74, 480, 489–91
 Logic-oriented programming. *See* Logic programming; Prolog
 Logic programming, 306, 309, 445–51, 461–80, 489–90. *See also* Logic vs. control
 concurrency, 465–66
 _{Logic-oriented programming, 306, 309, 445–51, 461–80, 489–90. See also Logic vs. control}
 procedural interpretation, 465–69
 LÖGO, 404, 406
 Long_Float, 249
 Loopholes. *See* Security Principle
 Loops. *See* Iteration
 loop-statement (Ada), 281–83
 Lovelace, Countess of (Augusta Ada), 245
 Lower case, 31n, 450
 LT. (FORTRAN less-than), 48
 Łukasiewicz, Jan, 313
 L_1 and L_2 (pseudo-codes), 11
- M (contents of memory location), 63
 Machine dependence and independence, 45–46, 70, 72, 95, 115, 120, 143–46, 249, 441
 Machine-oriented higher-order language, 45–46, 188–89, 205–8. *See also* Portability Principle
- Macintosh computer, 405
 MacLennan, B. J., 305n, 350n, 353n, 355n, 359n, 444n
 MacLisp, 312
 Macros
 Interlisp, 398
 syntax, 168–69
 MAD language, 168
 Mailbox, 294
 Maintenance, program, 26, 59, 81, 106–7, 123–25, 193–4, 200, 243, 263–5, 271, 300–1, 398, 459
 Manifest Interface Principle, 316–7, 416, 496
 Mantissa, 67
 map (LISP functional), 357, 360
 mapcar and mapcar2 (LISP functions), 351–52
 Mapping, finite (array), 181
 Mapping across a list, 346, 351–52, 357–58, 360, 427
 map2 (LISP functional), 358
 Mariner I, lost, 87
 Mark bit, 392–94
 Mark-sweep garbage collector, 392–94
 Masinter, Larry, 396n, 402
 Masterscope, 398
 Matching. *See* Unification
 mat-prod (function), 361–63
 Matrix multiplication, 361–63
 McCarthy, John, 309–11, 337, 344
 McIlroy's syntax macros, 168
 McLuhan, Marshall, 404
 Mean absolute value program, 20, 32, 42, 98, 171
 Meek, Brian, 91n
 member (predicate), 486
 Mesa, 205, 244
 Message dictionary, 431–32, 434
 Message port, 294
 Message sending, 294, 406, 414–18, 423–27, 434–36, 443
 Messages, Smalltalk, 406–8, 423–26
 cascaded, 408
 implementation, 434–36
 templates, 424–26, 431–32
 Metalanguage, 150–51
 Method (Smalltalk)
 class, 410–11
 implementation, 431–32
 instance, 410
 as procedure, 423–25
 Metric, grammar size, 303–5
 M-expressions, 311
_{M-expressions (FORTRAN)}
 minusp-fil (LISP function), 346–47
 Minus sign (-), 177
 double (Ada comment), 265
 Mission critical software, 244, 250
 Mixed-mode expressions, 69
 Models, 134–35, 411–12, 458–59
 Modes, parameter passing. *See* Parameter passing modes
 Modular, 205, 208, 244
 Modularization, 55–56, 243–44, 248, 263, 438. *See also* Information hiding; Modules; Packages; Procedures
 Modules. *See* Information hiding; Information Hiding Principle; Modularization; Packages; Procedures
 MOHOL (Machine-oriented higher-order language), 45–46, 188–89, 205–8
 Monitor. *See* Protected type
 Monotonic reasoning, 475

- Montessori, Maria, 404
 month (data type), 174, 184
 mother (predicate), 447
 Multiple inheritance, 421, 441–42
 Multiplication, matrix, 361–63
- Name access, 262, 264, 266
Name equivalence, 191–92, 251–53. *See also Type equivalence*
 Name parameters, 129–35, 162, 201, 222, 240
 Name space. *See Name structure*
 Name structure, 75–76, 92, 101–4, 163, 193, 205, 256, 363–64
 clutter, 353
 contour diagrams. *See Contour diagrams*
 records as, 185
 Naur, Peter, 96, 126, 148, 163
 Negation, 481–85
 NELIAC, 96
 Nesting. *See Hierarchical structure; Scoping*
 Neumann, John von, 8, 9
 new
 Ada generic instantiation, 271
 Ada storage allocation, 269
 Ada type declaration, 251–54, 438
 Pascal storage allocation, 189–90, 263, 337, 388–89
 Smalltalk instantiation, 411
 newAt: (message), 409, 411
 nil (atom), 319, 325
 Prolog definition, 452–55
 n1 (predicate), 478
 no (Prolog response), 448
 Nonexecutable statements. *See Executable statements vs. declarations*
 Nonlocal, 104. *See also Display; Local; Static chain*
 nonlocal access, 213–15, 382–88, 434
 Nonmonotonic reasoning, 475–76
 Nonnumeric data, 69–70, 172–75, 314–15, 318–19. *See also specific data types*
 Nonprocedural programming, 445–46, 459, 469, 473–74, 479, 490
 Nonterminal symbols, 150
 Norman, Donald, 134–35
 not (predicate), 483–85, 488–89
 Notation, 148, 362, 372. *See also Symbols at beginning of index*
 Not-equal, 482, 485–86, 488–89
 NPL (New Programming Language), 90. *See also PL/I*
 null (LISP function), 319
 Prolog definition, 452–53
 numberp (LISP function), 377
 Numbers. *See also Decimal numbers;*
 Numeric data types
 boldface, 362
 denotations, 148–54
 Numeric data types, 66–70, 115, 248–50, 252–54, 256, 317–18. *See also specific data types*
- Oberon (language), 205
 Object (object-oriented programming), 404–9, 421–22, 426, 429–30
 object class, 413, 431, 434
 self, 411
 self-displaying, 416–17
 Object code, 43–44
 Object declaration (Ada), 256
 Objectification of tools, 34
 Object language, 150–51
 Object-level vs. function-level, 359
 Object-oriented languages. *See Object-oriented programming*
- Object-oriented programming, 163, 277–78, 303, 306, 309, 399, 443–44, 458–59
 in Ada 95, 436–41
 in C++, 441
 in Java, 441
 in LISP, 441–42
 as simulation, 411–12, 427, 443–44, 486
 used loosely, 443n
 Object pointer or reference, 422, 433
 Occurs check, 460
 Offset, relative, 216–7, 240, 433
 onep (LISP function), 318
 Operator extension, 168–69, 264–65, 278–79, 415–18. *See also Extensibility*
 Operator identification, 278–79, 290–91
 Operator overloading. *See Overloading*
 Optimal coding (drum computers), 8
 Optimization, 7–8, 40, 44, 53, 73–75, 248, 399
 Optional parameter, 279, 289–91
 Optional syntax, 154
 or (LISP function), 344–45
 Ordinal type, 176. *See also Boolean type and values; char; Enumeration type; Subrange type*
 Orthogonality Principle, 13–15, 124, 136, 203, 263, 286–87, 418, 420, 442–43, 461, 489, 495–96
otherwise, 210
 out (Ada passing mode), 286–88
 Overlapping definitions, 258, 261–63, 267–68
 Overloading, 68–69, 248, 255–56, 264, 274, 278–79, 290–91, 415–16, 441
 own variables, 113n, 140, 263
- Packages, 248, 264–79, 436–40. *See also Class*
 generic, 270–76, 423–24, 441
 Pair, dotted, 326n, 453–55
 pairlis (LISP function), 353, 384
 Paper, Seymour, 404
 PAR (part of activation record), 63, 221
 Paradigm, 412, 443–44
 Parallelism. *See Concurrency*
 Parameter
 actual, 55, 162, 222, 227
 default, 279, 289–91
 formal. *See Formal parameter*
 hidden, 255
 optional, 279, 289–91
 position-independent, 279, 288–91, 425
 Parameter passing modes, 286–88
 constant, 202–3, 286–88
 functional, 203–4, 225–28, 240, 351–63, 367–70, 385–88
 implementation, 222, 274–76
 input, 202–3, 286–88
 input-output, 202–3, 286–88, 466–69
 input-output the same in Prolog, 466–69
 instantiation. *See Instantiation*
 internal vs. external representation. *See Representation, internal vs. external*
 Jensen's device, 110, 131–32, 313
 literal table corrupted, 59
 name, 129–35, 162, 201, 222, 240
 output, 286–88
 parameter inspection time, 134
 procedural. *See Parameter passing modes, functional*
 reference, 56–60, 134, 201–2, 222, 286–88
 result, 286–88
 swap procedure impossible in Algol-60, 132–34
 test procedures, 60–61, 130–31, 141
 thunk, 132, 140, 162, 202, 222
- typed vs. untyped, 99
 value, 128–29, 134, 162, 201–2, 222
 value-result, 60–61, 286–88
 PARC, Xerox, 396, 399, 404
 parent (predicate), 447
 Parentheses (LISP), 314–15, 319–20, 370–72
 Parnas, D. L., 81, 243, 280
 Parnas's Principles, 263. *See also Information hiding; Information Hiding Principle*
- Parser, 44, 86, 155, 248
 Pascal, 117, 119, 138–39, 163, 170–205, 211, 228, 235, 237, 245, 247–49, 251, 254–55, 257, 263, 281–82, 286, 289, 299–301, 303–6, 343–46, 372, 389, 395, 422, 446, 463–64, 480. *See also P-code*
 concurrent, 205, 306
 goals, 170
 history, 170–1
 Passive vs. active, 421–22
 Path, access, 185
 Path expression, 306
 pcc, 207
 P-code, 36, 170–71
 PDP computers, 206–7
 pen (Smalltalk class), 406–10
 pendn and penup (messages), 406–7
- Period
 double (..), 175, 252
 single (.), 184, 266, 269, 272, 274, 453–55
- Perlis, Alan, 96–97, 162–63
 person (record type), 184
 Personal computer, 403–5
 Phenomenology, 33–35, 404
 programming language as work environment, 160
 technology is nonneutral, 33, 35, 158
 values symbolized by aesthetics, 160
- Piaget, Jean, 404
 plane (record type), 187
 Plato, 404
 PL/I, 69, 90–91, 117, 146–47, 162, 164–165, 167–68, 189, 205–7, 249
 complexity criticized, 90, 167–68, 304
 as fatal disease, 90
 as plane, 167–68
 as Swiss army knife, 167
- plist (LISP function), 334n
 p-list, 324–26
- PLUS, 206
- plus
 LISP function, 317
 Prolog functor, 451, 455–57
- plus-red (LISP function), 346
- Plus reduction. *See Reduction of a list*
- Plus-sign
 Kleene cross, 153
 set union, 177
- PL360, 170, 208
- pname (LISP property), 331
- Pointer, dangling, 292–93, 389
- Pointer binding, 190
- Pointers. *See Pointer types; References and referencing*
- Pointer types, 189–91, 250, 440
- Polish notation, 313
- Polymorphic, operations, 68. *See also Generic packages; Overloading*
- Portability, 95, 143–46, 207–8, 303, 441, 459.
 See also Machine dependence and independence; Portability Principle
- Portability Principle, 46, 115, 143, 246, 287, 429, 496
- Position-independent parameter, 279, 288–91, 425
- Postfix format, 31, 456n

- Precedence of operator, 89, 168, 313, 425–26
 Precision, numeric. *See* Numeric data types
pred (Pascal function), 174–75
 Predicate (Prolog), 450
 input-output, 474
 Predicate logic, 481
 Predication (Prolog), 450
 Predictability, 135. *See also* Regularity; Regularity Principle
 Prefix format, 31, 456. *See also* Polish notation
 Preprocessors, 91
 Preservation of Information Principle, 53, 188–89, 249, 496
 Primitives vs. constructors, 70, 75
 Principles of programming language design, 3, 14, 495–96. *See also* specific principles
 applying, 14, 495–96
 collected, 496
print (message), 416–17
 Print name, 331–32
 Priority of operator, 89, 168, 313, 425–26
 Private
 part of package specification, 264–65
 type, 264–65, 273–74, 437–38
 Procedural abstraction. *See* Procedures
 Procedural parameters. *See* Parameter passing modes, functional
 Procedural programming. *See* Nonprocedural programming
 Procedures, 54–56, 127–34, 286–91, 423–26, 465–69. *See also* Declarations, procedure; Message sending; Parameter passing modes
 Ada, 247, 257, 264, 267–79, 286–91, 300
 Algol, 99, 127–34, 195
 anonymous. *See* Anonymous
 array parameters, 57–58, 128–29, 182–83
 as first-class citizens, 204
 FORTRAN, 54–56
 implementation, 61–66, 219–35, 239–40, 380–88, 432–36
 implementation notation, 63–64
 LISP, 317, 333–334, 351–57, 363–64, 367–71, 380–88
 Pascal, 172, 195
 Prolog, 465–69
 recursive, 127–28, 195–96
 Smalltalk. *See* Messages, Smalltalk;
 Method (Smalltalk)
 specification, 257
 Process, 240, 248, 291–99, 427–28
 prod (predicate), 457
 Product, inner or scalar, 352, 360–63
 prog feature (LISP), 345n
 Program vs. data, 9–10, 315–16, 421–22
 Program design notation, 8
 Programmer's Assistant, 397–99
 Programming
 difficulty of, 7
 experimental, 394–95, 398
 by extension, 436
 in the large, 56, 357–58
 reliable, 111–12
 software crisis, 243
 Programming environment. *See* Environment, program development
 Programming languages, 1–2. *See also* specific languages
 applicative vs. imperative, 313
 design, vs. feature design, 305
 featuritis, 304–5
 framework, 494–95
 future of, 497
 number of, 4, 244
 perfect, 493
 phenomenology. *See* Phenomenology
 reason for diversity of, 493–94
 size, 97
 small programs misleading, 5
 and values, 160
 as work environment, 160
 Programming in the large, 56
 Programming, nonprocedural. *See* Nonprocedural programming
 Programming, structured, 90–91, 125–26, 164, 195–97
 Program structure, 19–20, 31, 41, 97–98, 196
 Prolog, 445–90. *See also* Equality; Inequality; Logic programming; Negation
 cuts, 476–80, 490
 database, 447, 458, 475–76
 depth-first search, 469–71
 history, 446
 logic vs. control, 461, 469, 473–74, 480, 489–91
 order of clauses, 450, 461
 Propagation of exceptions, 284–85
 Properties of atoms. *See* Atoms, properties
 Property lists, 324–26
 Protected type, 297–99
 Protocol, class, 412, 416–17, 422
 Proving, automatic, 446, 459–60, 466, 469, 475–76
 Pseudo-codes, 7–33
 defined, 10
 operations (table), 19
 Smalltalk, 429, 432
 Pseudo-function, 316, 339
 Psychology, 134–35, 404
 Publication language, 145
 Pure function, 316, 321, 328, 338–39
 putprop (LISP pseudo-function), 332, 391n
 Quotation marks, single, 21n, 315, 351, 371.
 See also quote (LISP)
 quote (LISP), 371, 377, 379
 raise, 269, 284–85
 Range
 array attribute, 255
 constraint, 248–50, 254
 Range constraint, 248–50, 254. *See also* Subrange type
 RATFOR, 91
 read (predicate), 474
 Readability, 47–50, 86, 116, 118, 143–46, 148–50, 153–54, 193–94, 271, 279, 291, 301–2, 323, 343
 Read-execute cycle, 22, 316–17, 426–27
 Real numbers, 9–10, 36, 39, 66–69, 249
real type (Algol), 98, 115. *See also* Real numbers
 Records, 183–88, 251–52, 315, 455
 Recursive definition, 127, 151–52, 310, 447, 452, 454. *See also* Procedures, recursive
 base of, 127, 151–2
 and hierarchical structure, 348–50
 indirect, 155–56
 and induction, 329
 vs. iteration, 345–47, 350
 mutual, 195–96
 and top-down control, 461–63
 Recursively enumerable grammar and language, 154
red
 LISP functional, 358, 360
 Prolog predicate, 480–81
redo (Programmer's Assistant), 397
 reduce (LISP function), 352
 Reduction of list, 346, 352, 357–58, 360–61, 480–81
 Reductive vs. ampliative, 33–34, 162, 316, 396, 421, 480
 Reference, dangling, 292–93, 389
 Reference, object, 422
 Reference, pass by, 56–60, 134, 201–2, 222, 286–88
 Reference counts, 390–92, 394, 429, 435. *See also* Storage reclamation
 Reference language, 145
 References and referencing, 28, 57, 390, 422.
 See also Pointer types
 Refinement of classes, 413, 438, 440
 Regular grammar and language, 154–56
 Regularity Principle, 10–11, 13–16, 36, 70, 71, 101, 116, 117, 121–23, 136, 257, 285, 328, 408–9, 421, 425, 431, 442, 452, 495–96
 Relationship (Prolog), 450
 Relative offset, 216–7, 240, 433
 Relocation and relocatable format, 43–44
 remassoc (LISP function), 330
 Rendezvous, 293–99, 427
 repeat (predicate), 477–79
repeat-until, 47, 198. *See also* Iteration, indefinite
 Representation, internal vs. external, 276–78, 412, 418, 423–24, 436, 441–42
 Representation consistency, 398
 Representation independence, 67, 120, 244, 268, 459. *See also* Machine dependence and independence; Portability Principle
 Resatisfaction, 475
 Reserved words, 88, 146, 171
 Resolution algorithm, 460, 469, 481
 Responsible Design Principle, 114–15, 188–89, 389, 496
rest (LISP function), 337
 Restrictions. *See* Regularity Principle; Simplicity Principle; Zero-One-Infinity Principle
 Resumption address, 63–64, 220–21. *See also* Instruction part or pointer
 Retention vs. deletion, 240, 293n
 retract (predicate), 475, 478–79
 Return, implementation. *See* Procedures, implementation
 RETURN-statement, 54–55, 225. *See also* Procedures, implementation
rev (LISP functional), 357
 Reversing arguments, 357
 Richards, Martin, 206
 right (field), 335–36, 390, 397
 Ritchie, Dennis M., 206–8
 Robinson, J. Alan, 469, 481
 roots-aux (function), 365–67
 Roussel, Philippe, 446
 Row-major order, 72
 rplaca and rplacd, 339–40, 390–92, 397
 Rules (Prolog), 450
 run message, 426–28
 Run-time vs. compile-time, 11, 36–37, 41–44, 100, 215–18
 Ryle, Gilbert, 495
 Safety features. *See* Security; Security Principle
 Sammet, Jean, 40
 Sandewall, Eric, 396n, 402
 Santayana, George, 3
 Sapir-Whorf hypothesis, 2
 Satisfaction of goal (Prolog), 448, 481–85
 Scaler product, 352, 360–63

Scaling, manual, 9–10
 Scanner. *See* Lexics and lexical analysis
 Scheduling, Smalltalk, 427–28
 Scheme (programming language), 370, 388, 400
 Scientific dimension (three S's), 157
 Scope defining constructs, 212. *See also*
 Name structure; Scoping
 Scoping, 162. *See also* Context; Environment
 (name structure); Name structure;
 Visibility
 global, 78–79
 lines, 102
 local, 78
 records, 185
 static vs. dynamic, 107–12, 219–20,
 284–85, 365–70, 385–88, 400
 Scribe (Smalltalk object), 406–8
 sd, 216
 Second-class citizen. *See* First-class citizen
 Second-generation language. *See* Generations
 Security, 12, 36, 113, 119–20, 173–76, 179,
 186, 189–92, 200, 203–4, 207, 389–90,
 441. *See also* Security Principle
 Security Principle, 27, 29, 59–60, 70, 77,
 202, 419–20, 422, 442, 459, 495–96. *See also* Security
 Selection, component. *See* Selector
 Selection statements, 47. *See also* Case
 selection; Conditional selection
 Selector, 185–86, 320, 327–29
 implicit, 454–55
 select-statement, 296
 self (Smalltalk), 411, 414–15
 Self-documenting, 200–1, 489
 Self-embedding terms. *See* Infinite terms
 Self-referential structures. *See* Lists, circular
 or cyclic
 Semantics, 97, 163, 248
 Semicolon
 Prolog, 448, 468, 484
 terminating vs. separating, 300–1, 307
 Sender part (Smalltalk), 433. *See also*
 Dynamic link
 Separating semicolon, 300–1
 Sequential interpretation of logical
 connectives, 344–45, 349–50, 379
 set (LISP pseudo-function), 316–17,
 332–33, 363–64, 371, 391n
 set_equal (predicate), 487
 setq (LISP pseudo-function), 371
 Sets
 Pascal, 176–79
 Prolog, 486–87
 sex (data type), 174
 S-expressions, 311–12, 315, 319, 370
 sg (signum or sign function), 343–44
 Shallow binding method, 234
 Shared access, 80–84, 102–7, 112–14, 261–3,
 267–68, 338–40
 Shaw, Mary, 258, 262–63, 307
 Short_Float, 249
 sibling (predicate), 447
 Side effects, 59, 258–59, 262–63, 316
 signum (sign function), 343–44
 Simplicity, metric, 303–5
 Simplicity Principle, 116, 136–37, 168, 197,
 205–6, 208, 257, 314–5, 421, 442, 452,
 495–96
 Simula, 163, 244, 272, 277, 404, 412, 427,
 436, 441, 444
 Simulation, 411–12, 427, 443–44, 458–59
 Size, language metric, 303–5
 Sketchpad, 404
 SL (part of activation record). *See* Static link

Slash
 symbols. *See* Symbols at beginning of index
 through list cell, 335
 Smalltalk, 163, 272, 277, 399, 403–444. *See also*
 Class; Messages, Smalltalk; Method
 (Smalltalk); Object (object-oriented
 programming)
 history, 403–5, 444
 implementation, 428–35
 read-execute loop, 426–27
 snl, 216
 Social dimension (three S's), 157–58
 Software, experimental, 394–95, 398. *See also* Programming
 Software crisis, 243
 Source form, 32
 Space probe lost, 87
 Special names (LISP), 388
 Special needs annexes (Ada), 246, 303
 Specification, 248, 257, 305, 395, 398
 Speedcoding, 39
 Stack
 example, 268–78, 416
 runtime storage management, 100, 112–14,
 118–19, 211–40, 435–36
 Standards, programming language
 Ada, 245
 FORTRAN, 40, 91–93
 LISP, 312, 399–400, 441–42
 Pascal, 170, 182–83, 191–92, 195–96, 198,
 204
 PL/I, 165
 Scheme, 400
 Smalltalk, 404
 Star, Kleene, 153, 156
 State, of caller, 61–62, 218–21, 434–35
 Statement, empty, 300–301
 Static chain, 162, 214–15, 234, 434. *See also*
 Static link
 Static distance, 216
 Static vs. dynamic. *See* Dynamic vs. static
 Static vs. dynamic structure, 111. *See also*
 Structure Principle
 Static link, 213–15, 219–230, 236–38. *See also*
 Static chain
 Static nesting level, 216
 Steelman, 245
 Storage allocation. *See* Storage management
 Storage management, 28–30, 42, 100,
 112–14, 118–19, 127–28, 196, 211–40,
 388–394, 428–30, 432–36
 FORTRAN EQUIVALENCE, 84–85
 Storage reclamation, 388–94, 399, 429. *See also*
 Storage management
 Strawman, 245
 Strict interpretation of logical connectives,
 344–45, 349–50, 379
 string (type), 116–17, 184
 Strings, 69–70, 116–17, 173, 319, 415–18.
 See also Atoms
 Strong typing, 119–21, 190. *See also* Weak
 typing
 Stroustrup, Bjarne, 441
 Structural engineering, 156–60
 Structural equivalence, 191–92, 252. *See also*
 Type equivalence
 Structure, hierarchical. *See* Hierarchical
 structure
 Structured assembler, 206
 Structured programming, 90–91, 125–26,
 164, 195–97. *See also* Structure
 Principle
 Structure Principle, 48–49, 53, 91, 112, 126,
 144, 285, 302, 496. *See also* Structured
 programming
 Structures. *See also* Primitives vs.
 constructors
 heterogeneous data structures, 183–88,
 251–52, 315, 455
 LISP, 232n
 Strunk and White, *Elements of Style*, 14
 Style, influenced by tools, 34–35. *See also*
 Conventions; Strunk and White,
 Elements of Style
 Subclass, 412–15, 418–21, 437
 Subgoal generation, 461–65, 469–71
 Subprograms. *See* Procedures
 Subrange type, 175–76, 248–50, 252–55. *See also*
 Range constraint
 Subroutines. *See* Procedures
 Subset, language, 246, 249, 303
 Substitution, 56–57, 129–35, 140
 Subten symbol, 148
 Subtype, 251–54
 sub1 (LISP function), 317–18
 succ
 Pascal function, 174–75
 Prolog functor, 451–52
 Sugar, syntactic, 71, 181, 367, 453–54, 456
 sum (predicate), 451–52, 457–58, 471
 Summation function, 109–10, 131–32,
 254–55
 sup (functor), 455
 super (Smalltalk), 415
 Superclass, 413, 418–21, 431
 Superset, language, 246, 249, 303
 Suspending. *See* Activation and deactivation,
 procedure
 Swap procedure, impossible in Algol-60,
 132–34
 Sweep phase, 392–94
 Swiss army knife, 167
 switch-declaration, 98–99, 139–40
 Symbol
 defined, 28
 miscellaneous. *See* Symbols at beginning
 of index
 terminal vs. nonterminal, 150
 Symbolic differentiation, 451, 455–58
 Symbolic dimension (three S's), 157–59
 symbol-plist (LISP function), 334
 Symbol table, 28–29, 76–77, 215–16. *See also*
 Label table
 shared access example, 80–84, 105–7
 Symmetry. *See* Orthogonality Principle;
 Regularity Principle
 Synchronization, 293–99, 427
 Syntactic analysis (compilation), 44, 86, 155,
 248
 Syntactic Consistency Principle, 50, 300, 302,
 417–18, 496
 Syntactic structure. *See* Syntax
 Syntactic sugar, 71, 181, 367, 453–54, 456
 Syntax, 30–33, 88–90, 92, 97, 146–47, 164,
 299–302, 370–72, 395, 424–26
 two-dimensional, 409
 See also BNF; Extensibility; Lexics
 Syntax-directed editor, 248
 Syntax macros, 168–69
 System image, 135
 Systems implementation language, 45–46,
 188–89, 205–8
 Systems programming, 120, 189, 205–8,
 428–29. *See also* Systems
 implementation language
 t (LISP atom), 316
 Table. *See* Label table; Literal table; Symbol
 table
 Tacoma Narrows Bridge, 158–59

- Tag field, 187, 251
 Tagged type, 436–40
 tail (function), 360
 Tartan (programming language), 244, 307
 Tasks, 240, 248, 291–99, 427–28
 Teaching, languages for, 170–71, 205, 400
 Technology. *See* Phenomenology
 Teitelman, Warren, 396n, 402
 Template
 C++, 441
 generic package as, 271
 protected type as, 298
 Temporal reasoning, 475–76
 Temporaries, 61, 63–64
 Temporary bindings, 364–67
 Temporary variable (Smalltalk), 411, 433–34
 Ten, subten symbol, 148
 Term (Prolog), 450–55. *See also* Infinite terms
 Term equality, 471, 485–87
 Terminal symbols, 150
 Terminating semicolon, 300–1
 Theorem proving, automatic, 446, 459–60, 466, 469, 475–76
 Third-generation language. *See* Generations
 Thompson, Ken, 206
 Three E's, 157–59
 Three S's, 157–59
 Thunk, 132, 140, 162, 202, 222
 Time, in programming languages, 400–1, 443–44, 475–76, 480
 time (record type), 187
 times
 LISP function, 311, 318
 Prolog functor, 455–57
 timesRepeat (message), 408
 Times sign (code duplication), 218
 Tinman, 245
 TMP (part of activation record), 63
 Tokens, 87
 Tools
 descriptive, 148–50
 phenomenology. *See* Phenomenology
 programming. *See* Environment, program development
 Top-down control, 461–63
 Top-down design, 195
Tower and the Bridge, The, 157–60
 Tracing, 25–26
 Trade-offs, 302–3
 Trailing-decision loop, 47, 198
 trans (transpose function), 360
 Translation. *See* Compilation
 Transparency, 34, 174, 187, 203, 339, 389, 394, 396, 398, 443, 460, 473, 485, 489
 Tree, expression, 335, 455–58
 Truth values, 66, 98, 115, 319
 Turing Award, 167–68, 304, 307, 359, 363, 372
 Turing machine, 1n, 311
 turn: message, 407, 410
 Turtle graphics, 406. *See also* pen
 twice (functional), 367–69
 Two-coordinate addressing, 215–17, 240, 433
 type. *See* Type declaration
 Type conversions, 68–69, 120, 250, 255. *See also* Coercions
 Type declaration, 172, 191–3, 196, 248–54
 Type equivalence, 191–93, 251–54
 Type, protected, 297–99
 Type, tagged, 436–40
 Type 0, 1, 2, 3 grammars and languages, 154–55
 Typing. *See also* specific data types; Type equivalence
 loopholes, 70, 83–85, 187–88, 190
 static vs. dynamic, 100, 181–83, 186, 335, 394–95, 422–23, 440–42
 strong vs. weak, 50–51, 69–70, 119–21, 181–83, 204, 206–7, 422, 441
 typeless languages, 206
 Unary, 3n, 356, 472
 Unconstrained type, 254–55, 440. *See also* Constraint
 Undefined symbols, 27–29
 Undiscriminated union, 251
 undo (Programmer's Assistant), 397
 Unification, 454, 459–60, 462, 486, 488–89
 Union operation, 177, 179
 Union types, 251. *See also* Variant records
 Universal function, 310–11, 375
 Universal integer and real types, 256
 Universal Turing machine, 311
 Unix, 206–8, 304
 Unsatisfiability, 481–85, 488–89
 Upper and lower case, 31n, 450
 Upward compatibility, 305
 Upward funarg problem, 228, 372–73
 use command (Programmer's Assistant), 397
 use declaration, 266, 268–69, 274
 Users, don't ask what they want, 114–15, 188–89, 389, 496
 User's model, 135
 User task, 426–27
 Utopians vs. dystopians, 33–34, 40, 389
 Validation, compiler, 246
 Value, pass by, 128–29, 134, 162, 201–2, 222
 Value cell (Common LISP), 332n
 Value-oriented programming, 444n. *See also* Functional programming; Function-oriented programming
 Value-result, 60–61, 286–88
 Values (desirable traits), represented by languages, 160
value specification, 128. *See also* Value, pass by
var, 172
 Variable-free programming, 359–60, 363
 Variables
 accessing, by display, 231–32
 accessing, by shallow binding, 234
 accessing, by static chain, 215–18
 controlled, 51
 declarations. *See* Declarations, variable dummy. *See* Formal parameter
 instance, 409–11, 429–31, 433–34
 undefined, 27–29
 Variant records, 186–88, 254, 300. *See also* Discriminant; Union types
 Venus space probe lost, 87
 Verification, 245
 Vertical bar, 151, 411, 454n
 Viking (actually, Mariner I) lost, 87
 Virtual computer, 4, 10–11, 36, 428–29
 Virtual procedure, 441. *See also* Abstract subprogram
 Visibility, 78, 104, 135–36. *See also* Context; Contour diagrams; Name structures
 von Neumann, John, 8, 9
 Vulnerability, 111, 258, 260–63
 Weak typing, 50–51, 70, 100. *See also* Strong typing
 when (Ada), 282–83, 285, 297–98
while-loop, 47, 198, 282, 345. *See also* Iteration, indefinite
 Wilkes, Wheeler, and Gill book, 10
 Window-oriented display management, 405, 409, 443
 Wirth, Niklaus, 114–15, 170, 188, 205, 209, 305
with-statement, 185, 266–69
 Woodenman, 245
 Word-at-a-time programming, 359
 Work environment, 160
 write (predicate), 474, 478–79
 Wulf, Bill, 258, 262–63, 307
 Xerox PARC (Palo Alto Research Center), 396, 399, 404
 XPL, 206
Y. *See* Infinite terms
yes (Prolog response), 468
 Zero-One-Infinity Principle, 71, 117–19, 122, 146, 319, 346, 360, 413, 425, 495–96
 zerop (LISP function), 318
 zerop-map (LISP function), 348, 351
 Zones, 430
 Zuse, Konrad, 9